A

Research Proposal

on

Design of Generalized Framework for No Reference Color Image Quality Assessment

For the degree of

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By

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1. Introduction

Today we live in an era full of digital visual information. It is rightly said, **"One picture is worth more than thousand words"**. It is very true if quality of image is good. Humans use color information to distinguish objects, materials, food, places and time of the day. Human eye can discern among thousands of color shades as compared to only two dozen gray shades. Color is a powerful descriptor and simplifies representation and description of an image. Therefore quality of color information plays very important role in many applications such as digital imaging, multimedia systems, visual communications, computer vision, entertainment and consumer electronics.

However, the quality of digital image is rarely perfect. Artifacts can be introduced at various stages of processing chain which includes acquisition, compression, transmission or storage, decoding and display.

During acquisition of an image, following artifacts may be introduced due to the optical lens, the density and accuracy of the sensing elements or the digitization process.

1. Blurring can be introduced due to incorrect focus of camera or the motion blur.
2. Noise can be introduced because of the sensing elements of camera.
3. Contouring is generated due to low resolution of ADC.
4. Insufficient sampling frequency results into aliasing that causes color artifacts.
5. Inaccurate display characteristics also introduce the artifacts [25].

Artifacts are also introduced in processing stages of images.

1. During encoding process, block based compression (e. g. JPEG, MPEG-2) may introduce unique blocking artifacts in an image. Here lack of resolution in fine details because of quantization causes image smoothness or blur.
2. Color bleeding is the smearing of the color between areas of strongly differing chrominance. It results from the suppression of high-frequency coefficients of the chroma components. Many observers perceive this as a loss of colorfulness [23].
3. Wavelet-based coders (e. g. JPEG-2000) may introduce blurring, ringing and aliasing effects. [25].
4. Enhancement may introduce the artifacts that were not present previously in the image.

Thus digital color images suffer a wide variety of distortions that result in degradation of image quality. In order to maintain, control and enhance the quality of color images, it is important for image acquisition, management, communication and processing systems to be able to identify and quantify image quality degradations. Traditionally, image quality was evaluated by human subjects. A set of images is shown to a group of people and they are asked to record its perceived quality on predefined scale. Statistical average of such sample scores gives final quality score called as Mean Opinion Score (MOS). Such subjective test is the most accurate and reliable method. But this method is impractical, expensive and time consuming. To solve this problem, in past decades, many researchers took efforts to design novel image quality assessment (IQA) algorithm. The goal of such objective image quality research is to provide computational models that can automatically predict perceptual image quality that an average human observer will report. These objective image quality measures have great potential in a wide range of application environments.

- They can be used to monitor image quality in quality control systems.
- They can be employed to test and benchmark image processing systems and algorithms.
- They can be embedded into image processing and transmission systems to optimize the systems and the parameter settings [27].

Research in quality assessment methods has received increasing attention recently by the research community with the emergence of Video Quality Experts Group (VQEG) which is in the process of standardizing NR and RR video quality assessment methods [22], [13], [19]. Laboratory for Image and Video Engineering (LIVE) is set up at University of Texas at Austin to promote research in image quality assessment techniques.

2. Review of Literature

2.1 Classification of Objective Image Quality measures

Depending on the availability of an original image at the time of assessment image quality measures are broadly classified as Full Reference (FR), No Reference (NR) and Reduced Reference (RR) image quality measures [33], [12].

1. In FR quality assessment technique the assessment of distorted image takes place by comparison with the original image. In practice, FR algorithm is of limited use.
2. In RR quality assessment the original is not fully available. Instead, certain selected statistical features are extracted from the reference image and employed by the quality

assessment system as side information to help in evaluation of quality of the distorted image at receiver side.

3. When an image quality assessment system does not have access to the reference image NR quality assessment can be used to predict the quality score of distorted image without any information of reference image. NR quality measures need to incorporate characteristics of human visual system (HVS) in the metric [25].
4. Image quality metrics are further classified as grayscale image quality measures and color image quality measures. In color image quality measures, the quality is measured by pooling features related to intensity component as well as color components.

2.1.1 Full Reference methods of image quality assessment

First notable work documented in the field of objective image quality assessment in 1974 is the pioneering work of Mannos and Sakrison who proposed image fidelity criteria by considering human visual sensitivity as a function of spatial frequency [33]. Other important early work was documented in a book edited by Watson [33]. For the past few years the field of image quality assessment received relatively little attention, in spite of recognized importance. The research of developing quality assessment metrics was motivated by need to quantify the loss incurred by a compression algorithm or perhaps to assess the impact of a noisy communication channel. Historically, methods for image quality assessment were based on simple mathematical image fidelity measures such as the mean squared error (MSE) due to lack of knowledge of HVS, the structure and statistics of natural images. Though simple such metrics quantify only the global variations and neglect localized errors. They failed to detect structural errors that have a particular pattern. Many researchers [33], [4], [34] have either criticized or demonstrated severe limitations of MSE family. Ahmet M. Eskicioglu *et al.* In (1995) revealed that though few of the image fidelity measures predict image quality to some extent, they are not reliable. The measures are also categorized based on stability.

Z. Wang *et al.* (2006) proposed an efficient algorithm to quantify structural changes caused by various types of distortions which showed favorable results and attracted a lot of attention [33], [34], [35]. Authors believe that HVS is highly adapted to extract structural information from visual scenes hence structural similarity is used to approximate perceived image quality. Weighted combination of luminance comparison, contrast comparison and structure comparison gives the quality score. However performance of SSIM was observed to be less accurate for blurred and noisy images [2], [3], [17], [4]. It was because SSIM does not

consider visual importance of image features and neglects characteristics of HVS. Human eye is less sensitive to textured region than the smooth region. Hence the distortions in such textured or high frequency region are not perceived easily.

During 2007 to 2010 few researchers [4], [17], [2] reworked to improve the performance of SSIM by incorporating region based visual importance characteristics of HVS. They assigned content based weights to local SSIM value and to achieve this introduced edge information of image in SSIM which improved its performance for noisy and blurred images. B. Liao *et al.* [2] replaced structure comparison by edge similarity function that is based on macro and micro edges in image. Further the literature shows use of different pooling methods for mapping quality score to MOS obtained in subjective test.

To generalize the algorithm for color image quality evaluation, the direct way is to apply same metric to the three color channels and combine the errors. However, RGB color model does not describe colors with the way humans interpret colors. RGB channels are correlated with each other. The literature shows assessment of quality is made effective and efficient by use of other colorspaces which decouple luminance and chrominance information. Wandell presented a new color space, namely opponent colorspace in 1997 which was also called as Spatial CIELAB [21], [12] . In 2000 G. H Fahmy *et.al* [9] adopted this colorspace in IQA metric. Further [26] and [9] also show that small equal Euclidean distance in this space is recognized by human being. Y. Shi *et al.* [31] (2009) designed SHSIM, a color image quality metric as a weighted combination of structural similarity index from luminance channel and hue similarity index from chrominance channel. HSI colorspace is used by assigning higher weight to luminance channel than the chrominance channel.

As frequency domain image processing became common, P. Callet *et al*. (2003) proposed a measure of quality by combining error maps in spatial and frequency domain [19]. Human eye is much more sensitive to errors in low frequencies than in higher frequencies. M. Sendashonga *et al.* (2006) measured quality of image by using weighted RMSE in DCT or DWT domain where dissimilarity in lower frequencies was given more weight than in higher frequencies. In extension of this in 2008, Bo Wang *et al.* [3] and Chun Ling Yang *et al*.[5] proposed SSIM based method based on spatial (foveated vision) and frequency characteristics of human eye. Different weights are assigned to local SSIM value based on frequency components and spatial sensitivity [3] whileas [5] uses SSIM directly in discrete wavelet decomposition band where it is possible to weight local SSIM by different weights depending on quantization factor of that frequency band.

Current publications also show growth in use of wavelet domain because it preserves multi-channel and multi resolution characteristic of HVS. J. Li *et al*. (2012) presented an application of n level wavelet transform to decompose the image to get n+ 1 band and weigh differently by using Modulation Transfer function [16].

Recently with the advances in technology, Artificial Neural Network (ANN) is used to process the information as it is inspired by the biological nervous systems. Training and testing of ANN is performed to map known inputs to known outputs by using available LIVE database. Xiaonan *et al.* (2012) explored use of ANN to get quality score that correlates well with HVS from three inputs namely EPSNR in gradient domain, blocking and blur measures of distorted image [28].

2.1.2 Reduced Reference methods

The idea of RR quality assessment was first proposed in late 1990s as a means to track the degree of visual quality degradation of video data transmitted through complex communication networks. Traditionally a set of randomly selected pixels and their positions from reference image were transmitted with the image as a feature to assess the image quality. But it increased transmission overhead. Many attempts were made to select a perceptually relevant feature that gives efficient summary of image and needs a low data rate.

T. M. Kusuma *et al.* (2003) proposed a reduced reference perceptual quality metric that can be used in real time systems to evaluate quality of image [15]. Weighted sum of blocking, blurring, image activity measure and intensity masking detection is used to give quality of image. In extension to this G. cheng *et al.* [8] used edge information. Feature was obtained using Kullback Leibler Divergence (KLD) for distribution in gradient domain. Recently again Martini *et al.* [18] made use of edge sensitivity property of human eye and the fact that natural images obey specific statistics in gradient domain. The algorithm extracts block based features from gradient domain. The authors suggest use of Run Length Coding of the features to reduce the transmission overhead.

Like FR methods, wavelet transform can improve performance of the metric. Z. Wang *et al.* (2006) proposed a metric that uses Kullback Leibler Divergence (KLD) of distribution in gradient domain as a hidden message which can be used by the same image at the receiver to quantify the quality [37]. This embedded feature may be used to improve quality of image. Aldo Maalouf *et al*. (2009) used grouplet transform to integrate HVS properties in the model and efficiently measure the discrepancy between the two images in terms of orientation and

textures [1]. Grouplet bases are constructed in wavelet coefficients which allow to study the geometry of images at different scales. In the same year, Y. Ming *et al*. proposed a RR metric for color images by combination of hue and saturation based features in spatial domain and intensity based feature in wavelet domain to predict quality of JPEG and JPEG 2000.

G. Cheng *et al*. (2012) proposed a model using natural scene statistics characteristic in gradient domain using mean, variance, kurtosis, KLD as features [10]. Distortion introduced in the image causes deviation in distribution in gradient domain of natural images.

2.1.3 No Reference methods

In many practical applications, an image quality assessment system does not have access to the reference images. Blind or no reference image quality assessment technique predicts the image quality score without reference of original image. As it is a difficult task, it was paid a little attention. Literature shows the first attempt to design block edge impairment metric for video coding was made by H. R. Wu [36].

Under assumption that HVS is very sensitive to edge information, Z. Wang *et al.* (2002) proposed a no reference quality assessment metric for JPEG compressed images [36]. The metric used extracted features to reflect the relative magnitude of blocking and blurring artifacts. The extracted features are combined to constitute quality prediction model. In the same year P. Marziliano *et al.* [20] proposed a perceptual blur metric based on spread of edge. The drawback in this method is model parameters are derived from training data using subjective test. So the generalization is poor.

Further in 2006, Y. Yu *et al.* [29], made an attempt to develop an algorithm to predict perceptual quality of JPEG images by using General Regression Neural Network to map blocking, intra-block blurring and inter-block blurring features into a quality score. Due to high coding performance, JPEG 2000 coder is getting more attention instead of JPEG coder. Therefore Z. M. Parvezz Sazzad *et al*. [32] extended the work to design a metric based on pixel distortion and edge information to give more insight to blurring and ringing artifacts.

As functional relation between HVS features and MOS are nonlinear and is difficult to model neural networks are best suited to solve such problems. S. Suresh *et al.* (2009) proposed integration of extracted human visual sensitivity factors such as edge amplitude, edge length, background activity and background luminance to predict quality of image without any reference with ELM algorithm to assign the weight to factors [22]. Due to extensive use of color in multimedia and other applications, Zheng- Xiang Xie *et al.* (2010)

extended the work to assess quality of color images. Quality is predicted based on four vision parameters perceived by HVS [38].

However all these methods assumed a predefined distortion in the image. Jing Zhang *et al*. (2011) presented a general no reference metric to evaluate quality of image distorted with blocking, noise, blur etc [13]. The metric estimates quality of image by quantification of Structural Activity information weighted by its visual significance. Recently S. Lee *et al*. [24] proposed a new image quality assessment method to detect and measure strength of blocking artifact by using image in gradient domain. The measure excludes true edges in the image.

Natural Scenes belong to a small set in space of all possible signals and they contain nonlinear dependencies that are disturbed by the artifacts. Natural Scene Statistics model is used recently by D. Zhang *et al.* [6] Image is decomposed using Independent Component Analysis. Kullback Leibler Divergence is used to measure feature variation between natural scene and distorted image. It performs better for noise and blur as they are natural distortions.

Limitations of present work

1. **General purpose no reference metrics- at preliminary stage**

Image fidelity measures like peak signal to noise ratio (PSNR) and mean squared error (MSE) are the most widely used objective image quality measures in FR quality metrics. But they quantify only the global differences and fail to quantify the local differences. They are widely criticized as the results obtained are not consistent with quality perceived by human visual system (HVS) [33], [32], [8], [7].

In recent decades, new methods that take advantage of the characteristics of HVS, such as structural similarity (SSIM) are developed to tackle the above problems. SSIM attempts to extract structural information and to incorporate it in image comparisons [33], [11], [34]. However it is not so effective in some cases such as Gaussian noise image and blurred image [17], [4], [2], [3], [16]. The authors have suggested that a smoothly varying foveated weighting model need to be employed to define weights of each element of SSIM index map as it has been observed that different image textures attract human fixations with varying degrees [34].

Most of the image quality approaches proposed in the literature require the original image as a reference. But they cannot be used in applications where the original image is not

available. The problem is solved by RR or NR image quality measure. However available literature shows research in NR quality measurement is at preliminary stage. Most of the metrics are designed for a limited number of predefined distortion types [24], [13], [10]. Such methods obviously fail for any other distortion types. Further, mapping the computed quality score to MOS is a difficult task and the improvement is possible using efficient technology.

2. Need of effective use of chrominance component in color image quality assessment

Color information along with the structural information is important in evaluation of quality of color image. But most of the available literature shows that color image quality assessment is generally performed by assessing its luminance plane through grayscale image quality assessment methods. Thus a lot of color information remains unused [30], [14]. There is always some loss in color or deviation in color component due to artifacts and distortions that can influence human beings' judgments [31] and hence can contribute to the performance of quality score [30]. There are many attempts to extend other spatial domain error measures to color images by applying them to individual color channels and combining the results. In particular these methods treat errors in three color channels independently. However there are situations in which distortions can simultaneously affect several color channels which is normally ignored.

Literature shows very little meaningful progress in color image quality assessment in spite of its need in today's world of information. Design of general purpose no reference image quality metric is a challenging and wide open research area. Hence the focus of proposed research work will be assessment of color image quality using no reference technique.

3. Definition of problem

To design and develop a feature based framework for assessing quality of color in compressed and other images

4. Objectives and issues

Based on the literature survey as reported, gaps in present studies and the understanding established, the following objectives are proposed-

- To study various subjective and objective approaches for gray/color image quality measures/assessment techniques

- To design full reference HVS based color image assessment quality measure based on different color spaces
- To study deviations of color information and various features of images due to compression
- To develop no reference quality measure to determine the general quality of images

The literature reveals different issues and challenges that the designers of quality metrics face.

i. Subjective viewing data are essential for verification of performance of a quality metric. The proposed metric must be evaluated with a wide variety of visual contents and distortion types to make meaningful conclusion about its performance.

ii. In full-reference image quality assessment the original image is assumed to have perfect quality. The evaluation of distorted image takes place by comparing it with original image. But in some situations original image may not have perfect quality. For example, in contrast enhancement the quality of output image is superior to the quality of original image. This situation is exactly contradictory to the assumption.

iii. No-reference image quality assessment is the most difficult task in the field of image analysis. General-purpose NR image quality metric is a more complex system as it handles several modes of artifacts. The metric must be designed to assess the unknown distortions introduced in the images in future.

iv. In NR measures the assumed statistical knowledge describing high quality images is not restricted to a single original image. But it is expressed as probability distribution of all high quality natural images that fall within the space of possible images.

v. Using limited input information NR metrics must be able to distinguish signal from visible distortion. Many desired signals may look very similar to typical artifacts.

vi. Human visual system is complex and a complete model of the human is impossible. Sensitivity of HVS to different errors is different and varies with visual context.

vii. Mapping of computed quality score to corresponding MOS value to reflect the way the HVS and the brain arrive at an assessment of the perceived distortion is a difficult task.

5. Scope of study

The focus of this research work will be more to provide comparative study and analysis in different colorspaces. Feature based quality measure will be designed for

assessment of distorted image using full reference technique. It will lead to extraction of effective color parameters that measure the color loss more efficiently and further to establish relationship between blockiness measure and deviation in color in different colorspaces.

The ultimate aim of this research is to design a general color image quality metric to measure blocking, blurring and ringing artifacts without any reference of original image. The metric will be developed in spatial domain as well as frequency domain using publicly available image database for subjective viewing. Proposed metric can be used to monitor image quality for quality control systems. For example, a network server can examine quality of the digital image transmitted on the network.

6. Methodology, tools and techniques

Methodology in this research proposal involves different methods since the objectives cover full reference as well as no reference techniques. A schematic framework for objective quality assessment of color images is presented in figure 1.

Mainly such framework consists of three stages: Feature extraction, prediction/measurement of distortions based on features, pooling to yield single scalar quality score.

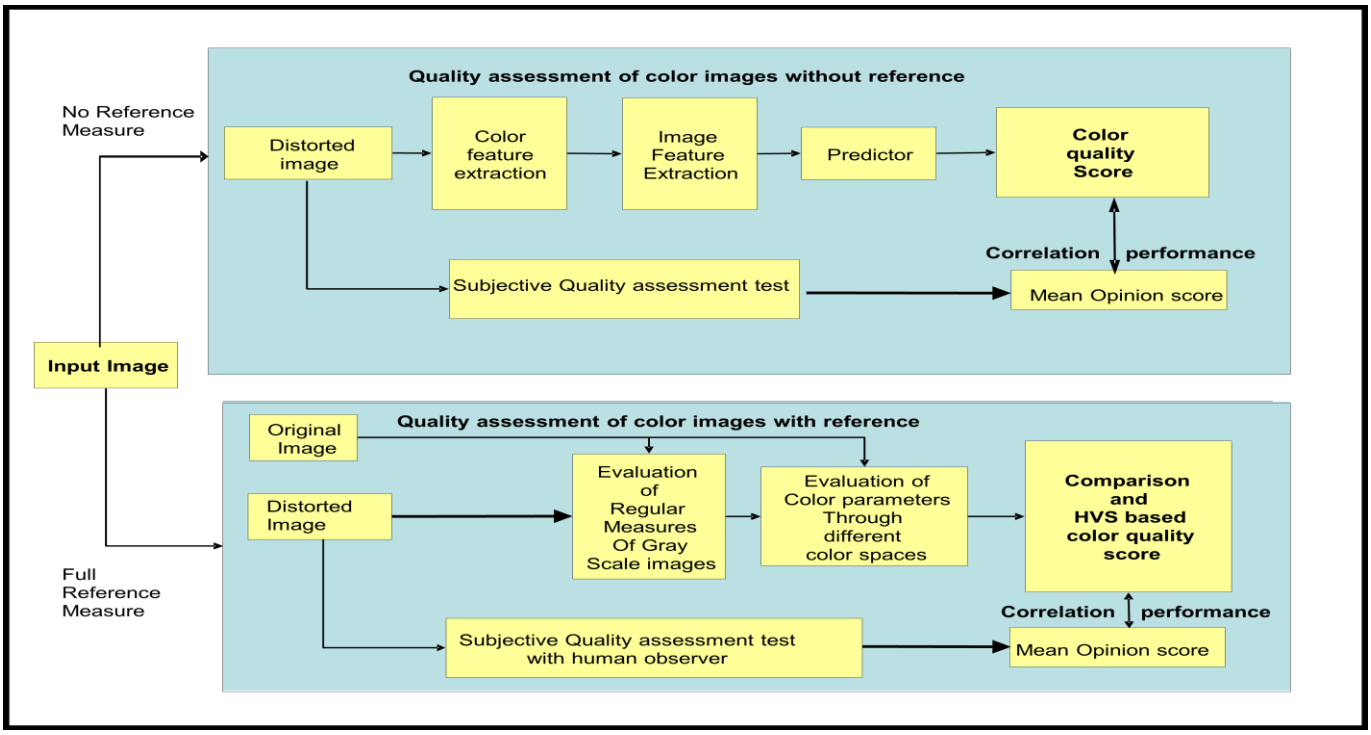

Figure 1 Block diagram of proposed metric

- Features that measure color loss and various possible distortions from all types of images including JPEG and JPEG2000 are extracted and a universal dataset of the features is prepared.
- If the feature data generated is very large, dimensionality reduction may be achieved using Principal Component Analysis (PCA) to generate significant feature vectors.
- The fuzzy or neurofuzzy based classifier will be trained using features extracted. Then the trained fuzzy classifier associates the selected features from test images with the corresponding predictions of quality ratings. The fuzzy classifier is used to suppress the subjectivity of image quality.

Finally, the performance of the metric can be evaluated with respect to MOS values in subjective database by measuring prediction accuracy, monotonicity and consistency

Tools and techniques useful to design proposed framework are discussed below-

MATLAB will serve as a programming tool which is developed by MathWorks for algorithm development, data analysis, visualization and numerical computation.

The toolboxes of MATLAB that are useful to design an image quality assessment metric are

- Image processing toolbox: It provides a comprehensive set of reference-standard algorithms and graphical tools for image processing, analysis, visualization and algorithm development.
- Statistics toolbox: It provides algorithms and tools for organizing, analyzing and modeling data. It also helps to evaluate performance of the metric by computing prediction accuracy, monotonicity and consistency. Principal Component Analysis (PCA) is used for dimensionality reduction.
- Neural network toolbox: It provides tools for designing, implementing, visualizing and simulating neural networks. Neural networks are used for mapping of computed quality score to HVS consistent quality score.
- Wavelet toolbox: It is used to analyze and synthesize signals and images using wavelet techniques.
- Fuzzy logic toolbox: It helps to design and simulate fuzzy logic systems. It provides MATLAB functions, graphical tools for analyzing, designing and simulating systems

based on fuzzy logic. The toolbox helps to model complex system behaviors using simple logic rules and then implement these rules in a fuzzy inference system.

Techniques that will be used to design the metric:

- Algorithm to measure distortions will be developed using Image processing toolbox and statistics toolbox available in MATLAB.
- If features extracted have higher dimensions then Principal Component Analysis can be used to reduce dimensions.
- For mapping the computed quality score to Mean Opinion Score (MOS) value Artificial Neural Network will be used.
- Finally, statistical measures like correlation coefficient, outlier ratio will be used to evaluate performance of the metric.

7. Plan of research work

Time / Activity	Sem I	Sem II	Sem III	Sem IV	Sem V	Sem VI
Literature review	←	—	→			
Study of existing measures and implementation of color feature extraction schemes in different color spaces for full -reference image quality measures	←	—	→			
Implementation and evaluation of performance of full –reference color image quality metric		←	—	→		
Design of no-reference color image quality measure			←	—	→	
Comparison with existing color image quality				←	—	→
Writing and communicating research papers to journals/conferences			←	—	—	→
Thesis writing						← →

References

[1]. Aldo Maalouf, Mohamed-Chaker Larabi, Christine Fernandez-Maloigne, "A grouplet based reduced reference image quality assessment", *Proceedings of IEEE Conference on Multimedia Experience*, 2009, pp. 59-63

[2]. Bin Liao and Yan Chen, "An image quality assessment algorithm based on dual scale edge structure similarity", *IEEE International Conference on Innovative Computing, Information and Control*, ICICIC 07, 2007

[3]. Bo Wang, Z. Wang, Yupeng Liao, Xinggang Lin, "HVS –based structural similarity for image quality assessment", *Proceedings of International Conference on Image Processing* , 2008, pp.1194-1198

[4]. Chaofeng Li and Alan Bowik, "Content-partitioned structural similarity index for image quality assessment", *Journal of Signal Processing and Image Communication*, 25, 2010, pp. 517-526

[5]. Chun-Ling Tang, Wen-Rui Gao, Lai-Man Po, "Discrete wavelet transform-based structural similarity for image quality assessment", *Proceedings of International Conference on Image processing* , 2008, pp. 377-380

[6]. D. Zhang, Y. Ding, and N. Zheng, " Natural scene statistics approach based on ICA for no-reference image quality assessment", *International Workshop on Information and Electronics Engineering(IWIEE),* Procedia Engineering, 29, 2012, pp. 3589-93

[7]. Dietrich Van der Weken, Mike Nachtegael, Etienne Kerre, "Combining neighborhood-based and histogram similarity measures for the design of image quality measures", *Journal of Image and Vision Computing*, 25, 2007, pp. 184-195

[8]. G. Cheng, L. Cheng, "Reduced reference image quality assessment based on dual derivative priors", *Electronic letters,* , vol. 45, no. 18, 27th August 2009, pp. 937-939

[9]. G.F. Fahmy and L.J. Karan, "Prediction of the quality of JPEG-compressed color Images based on the SCIELAB Metric", *IEEE Records of the Thirty-fourth Asilomar Conference on Signals, Systems and Computers*, vol. 2 , 2000, pp. 1054-1057

[10]. Guangquan Cheng, Jincai Huang, Zhong Liu, Cheng Lizhi, "Image quality assessment using natural image statistics in gradient domain", *International Journal of Electronics and Communication (AEO),* 65, 2011, pp. 392-397

[11]. Hua-Wen Chang, Ming-hui Wang, "Sparse correlation coefficient for objective image quality assessment", *Journal of Signal Processing and Image Communication,* 26, 2011, pp. 577-588

[12]. Ismail Avcıbas, Bu¨ lent Sankur, Khalid Sayood, "Statistical evaluation of image quality measures", *Journal of Electronic Imaging, vol. 11(2),* April 2002, pp. 206–223

[13]. Jing Zhang, Thinh M.Le, S. H. Ong, Truong Q, Nguyen, "No- reference image quality assessment using structural activity", *Journal of Signal Processing and Image Communication,* 91, 2011, pp. 2575-2588

[14]. Judith A. Redi, Paolo Gastaldo, Ingrid Heynderickx, Rodolfo Zunino, "Color distribution information for the reduced- reference assessment of perceived image quality", *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 20, no. 12, December 2010, pp. 1757-1759

[15]. Kusuma T.M., Zepernick H.-J., "A reduced reference perceptual quality metric for in-service image quality assessment", *Joint First Workshop on Mobile Future and Symposium on Trends in Communications, SympoTIC '03.* 2003, pp. 71-74

[16]. Li J., Wu K., Zhang X. and Ding M., "Image quality assessment based on multi-channel regional mutual information", *International Journal of Electronics and Communication(AEO),* 2012, in press

[17]. Liu Junyao and Wang Huijing, "Image quality assessment based on structure and edge similarity", *Proceedings of Fourth International Conference on Intelligent Computation Technology and Automation,* 2011, pp. 1105-1108

[18]. Maria G. Martini, Chaminda T. E. R. Hewage, Barbara Villarini, "Image quality assessment based on edge preservation", *Journal of Signal Processing and Image Communication,* 2012, in press

[19]. Patrick LE Callet, D. Barba, "A robust quality metric for color image quality assessment", *Proceedings of SPIE Visual Communications and Image Processing*, vol. 5150, Lugano, Switzerland, 2003, pp. 1573-1581

[20]. Pina Marziliano, Frederic Dufaux, Stefan Winkler and Touradj Ebrahimi, "A no-reference perceptual blur metric", *Proceedings of IEEE International Conference on Image Processing*, 2002, pp. 57-60

[21]. Roberto Fonseca, M. Ramirez, "Using SCIELAB for image and video quality evaluation", *Proceedings of IEEE International Symposium on Consumer Electronics*, ISCE 08, 2008, pp. 1-4

[22]. S. Suresh, R. Venkatesh Babu, H. J. Kim, "No-reference image quality assessment using modified extreme learning machine classifier", International Journal on *Applied Soft Computing*, 9, 2009, pp. 541-552

[23]. Sabine Susstrunk, Stefan Winkler, "Color Image Quality on the Internet", *Proceedings of IS&T/SPIE Electronic Imaging 2004*, vol. 5304, 2004, pp. 118-131

[24]. Sangwoo Lee, Sang Ju Park, "A new image quality assessment method to detect and measure strength of blocking artifact", *Journal of Signal Processing and Image Communication*, 27, 2012, pp. 31-38

[25]. Sheila S. Hemami, Amy R. Reibman, "No-reference image and video quality estimation: Applications and human-motivated design", *Journal of Signal Processing and Image Communication*, 25, 2010, pp. 469-481.

[26]. V. Tsagaris, G. Christoulas, and V. Ana stassopoulos, "A measure for evaluation of the information content in color images", *Proceedings of IEEE International Conference* of Image Processing, (ICIP), 2005, I -417-20

[27]. Welshi Lin, C.-C. Jay Kuo, "Perceptual visual quality metrics: A survey", *Journal on Visual Communication and Image Representation*, 22, 2011, pp. 297-312

[28]. Xiaonan Cui, Zhiyuan Shi and Lianfen Huang, "The research of image quality assessment methods", *Proceedings of International Conference on Solid State Devices and Materials Science*, Physics Procedia, 25, 2012, pp. 485-491

[29]. Yanwei Yu, Z. Lu, H. Ling and F. Zou, "No-reference perceptual quality assessment of JPEG images using general regression neural network", *Proceedings of Third International Conference on Advnaces in Neural Networks*, ISNN'06, 2006, pp. 638-645

[30]. Y. Ming, L. Huijuan, G. Yingchun, Z. Dongming, "A method for reduced-reference color image quality assessment", *Proceedings of IEEE International Conference on Image and Signal Processing*, 2009, pp. 978-982

[31]. Y. Shi, Y. Ding, R. Zhang and J. Li, " Structure and hue similarity for color image quality assessment", *Proceedings of IEEE International Conference on Electronic Computer Technology*, 2009, pp. 329-333

[32]. Z. M. Parvez Sazzad, Y. Kawayoke, Y. Horita, " No-reference image quality assessment for JPEG 2000 based on spatial features", *Journal of Signal Processing and Image Communication* 23, 2008, pp. 257-268

[33]. Z. Wang and A. C. Bowik, "*Modern image quality assessment",* Morgan & Claypool Publisher, 2006

[34]. Z. Wang, A. C. Bowik, H. Sheikh and E. Simoncelli, "Image quality assessment: from error visibility to structural similarity", *IEEE Transactions on Image Processing*, vol. 13, no.4, April 2004, pp. 600-612

[35]. Z. Wang, A. C. Bowik, Lingana Lu, “Why image quality assessment so difficult?”, *Proceedings of IEEE International Conference on Accoustic, speech and Signal Processing, vol. 4, (Orlando),* May 2002, pp. 3313-3316

[36]. Z. Wang, H. R. Sheikh and A. C. Bovik, “No-reference perceptual quality assessment of JPEG compressed images”, *Proceedings of IEEE International Conference on Image Processing*, 2002, pp. 477-480

[37]. Z. Wang, Guixing Wu, Hamid Sheikh, “Quality-aware Images”, *IEEE Transactions on Image Processing*, vol. 15, no. 6, June 2006, pp. 1680-1689

[38]. Zheng-Xiang Xie and Zhi-Fang wang, “Color image quality assessment based on image quality parameters perceived by human vision system”, *Proceedings of International Conference on Multimedia Technology (ICMT),* 2010, pp. 1-4